Faculty and Researcher Publications

2010-03

Team 9: Evaluation of a USMC Maritime Prepositioning Force Arrival and Assembly Model

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INTRODUCTION

The U.S. Marine Corps' Maritime Prepositioning Force (MPF) enables the rapid deployment of Marine forces to permissive areas of operations. The MPF consists of more than a dozen ships divided between three squadrons. Each squadron supports a notional Marine Expeditionary Brigade (MEB) and is based in one of three locations: the Pacific Ocean, the Indian Ocean, or the Mediterranean.

MPF Operation

During an MPF operation, a Maritime Prepositioning Ship Squadron (MPSRON) or some portion or combination thereof, is deployed to a permissive area of operations where its equipment and supplies are offloaded. A fly-in echelon (FIE) compromising the bulk of personnel and additional equipment is flown into a nearby airport. The equipment and personnel are then integrated to form a functioning Marine Air Ground Task Force (MAGTF). This process is called Arrival and Assembly.

Motivation

Operations Enduring Freedom and Iraqi Freedom (OEF/OIF) have caused rapid modernization of the USMC's equipment systems since 2003. This equipment is now being incorporated into the MPF program with potential impacts on Arrival and Assembly. An example is the armoring of the Medium Tactical Vehicle Replacement (MTVR), which is 'reduced' for embarkation on ship. During Arrival and Assembly, the MTVR armor needs to be reconfigured; a three-hour process requiring two mechanics and a piece of Material Handling Equipment (MHE) with its operator.

The tradeoff between resources (mechanics, container handlers, etc.) and the force generation timeline during MPF Arrival and Assembly is of particular interest.

Analytical Framework and Goals

An analytical framework is illustrated in Figure 1. The goal of this work at IDFW 20 is to use data farming techniques to analyze an MPF Arrival and Assembly model to inform data collection efforts for future MPF operations and/or exercises.

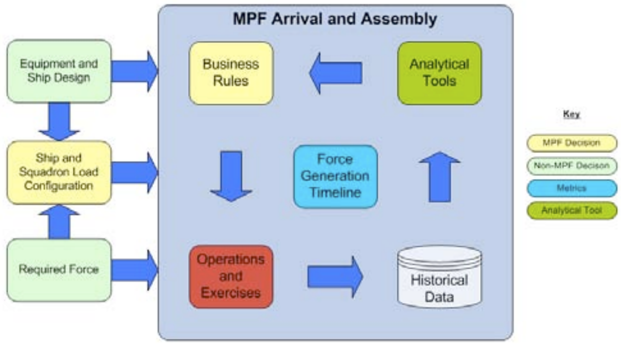

Figure 1. MPF Arrival and Assembly Analytical Framework

ARRIVAL AND ASSEMBLY MODEL

The MPF Arrival and Assembly Model is a discrete event simulation implemented in ExtendSim7. The model has two main processes: the offload of equipment from a ship to a pier and the throughput of equipment from the pier to its using unit located some distance from the pier.

Offload

The offload process models the interaction between ships and docks, where a dock is required to conduct an offload. Multiple docks allow for the simultaneous offload of ships. There are two methods for offloading equipment from a ship:

1. Roll On Roll Off (RORO) is used for vehicles that can be driven off the ship via its stern ramp. RORO requires both a ramp (ship asset) and offload drivers.
2. Lift On Lift Off (LOLO) is used for offloading containers (and possible vehicles) by lifting them with either a ship crane (ship asset) or a gantry crane (dock asset).

All the equipment is offloaded in a random order from the ship with all vehicular equipment using RORO and all containerized equipment using LOLO.

Throughput

The throughput process models the physical movement of equipment from the pier to the using unit and any maintenance or setup actions that must be completed to make equipment operational. The equipment is classified by type with each type requiring various assets during throughput as identified in Table 1.

Throughput Assets	Equipment Type				
	AMMO	ISO	RS	MTVR	HET
Throughput Driver			X	X	
Mechanic			X	X	X
RTCH, Pier	X	X			
RTCH, CSA	X	X			
Armor Teams				X	
Truck		X			
Truck Convoy	X	X			
Driver Convoy			X	X	
HET Convoy					X
Security Convoy	X	X	X	X	X

Table 1: Throughput Asset and Equipment Dependencies

The equipment must undergo various sub-processes dependent upon equipment type and additional factors such as a piece of equipment being 'frustrated' (dead lined and requiring maintenance) at the time of offload. The dependencies between throughput assets and sub-processes are identified in Table 2.

Model Parameters

Each of the offload and throughput resources is a parameter that can be controlled in the model. Additional parameters are:

1. Ship Crane Delay - time required to offload a piece of equipment using a ship crane.
2. Gantry Crane Delay - time required to offload a piece of equipment using a gantry crane.
3. Ramp Delay - time required to offload a piece of equipment using a ramp.
4. Return Offload Driver Delay - time required for an offload driver to return to the ship and be available to offload another vehicle.
5. Rough Terrain Container Handler (RTCH) Delay - time required to load/unload a container on a truck.
6. Truck Speed - speed at which a truck for moving ISO containers moves within the port.
7. Pier to Container Storage Area (CSA) Distance
8. Frustrated Delay - time required for a mechanic to repair a frustrated piece of equipment.
9. Frustrated Rate - probability that equipment is frustrated at offload.
10. SL3 Delay - time required to set up SL3 equipment on vehicles.
11. Mechanic Priority - the relative priority of SL3 vs. frustrated equipment for mechanics.
12. MTVR Armoring Resources - the number of resources dedicated to armoring MTVRs.
13. Rolling Stock (RS) to Movement Control Center (MCC) Delay - time required to move RS vehicles from the pier to the MCC staging area where they are formed into convoy sticks by destination.
14. Port to Destination Distance - distance from the port to the final destination. Each destination is an independent variable.
15. Convoy Delay at Destination
16. Convoy Priority - priority for assigning security assets to convoys.

Scenario

In this scenario, we model a single MPSRON offload. The MPSRON has 4,298 Principle Equipment Items (PEIs) spread across four ships with the following breakdown by equipment type:

- ISO (General Cargo Containers) 42%
- RS (Rolling Stock Vehciles) 32%
- AMMO (Ammo Containers) 14%
- MTVR (Sub-set of Rolling Stock) 7%
- HET (Tracked Vehicles) 5%

Metrics

Figure 2 is a screen shot of the model outputs. The blue, green and red lines represent the counts of equipment over time at the pier, at the final destination, and in the throughput process respectively. We use days to complete offload, the days to complete throughput and the mean cycle time of equipment (time complete - time offloaded) as our primary metrics.

Throughput Assets	Throughput Sub-Processes					
	Frust-rated	SL3 Setup	Move ISO Pier to CSA	Move RS Pier to MCC	Armor MTVRs	Convoy To Using Unit
Throughput Driver				X		
Mechanic	X	X				
RTCH Pier			X			X (Ammo)
RTCH CSA			X			X (ISO)
Armor Teams					X	
Truck			X			
Truck Convoy						X
Driver Convoy						X
HET Convoy						X
Security Convoy						X

Table 2: Throughput Assets and Sub-Process Dependencies

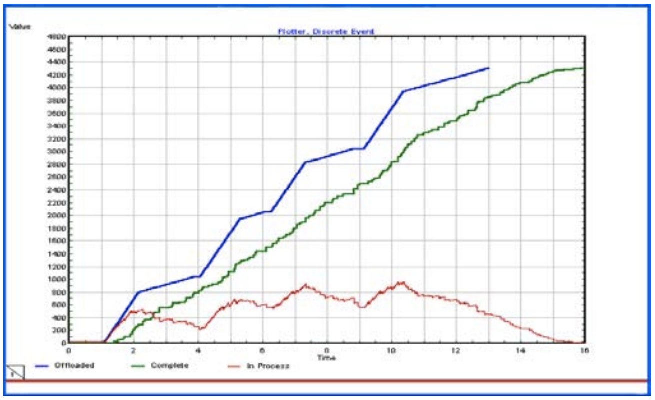

Figure 2. Simulation Output. The blue line identifies the count of equipment as it is offloaded at the pier. The green line is the count of equipment as it arrives at the final destination. The red line is the count of equipment in the throughput process. The primary metrics in the simulation are the day offload is completed, the day throughput is completed, the mean flow time (time complete - time offloaded) of equipment in the throughput process.

Factor	| Effect |
gcrane	192.60638
dock	174.58188
dock:gcrane	73.28010
scranedelay	39.67487
gcrane:scranedelay	35.61884
gcranedelay	21.38376
returndelay:offloaddriver	15.53665
dock:scranedelay	14.69414
dock:gcranedelay	13.08632

Table 3. Top nine factors including two-way interactions that effect the time to offload

DESIGN OF EXPERIMENTS

We use a 28-factor Nearly Orthogonal Latin Hypercube (NOLH) design of experiments with 200 design points. Each design point was run 30 times for 7,200 total runs.

RESULTS

Offload

The use of gantry cranes and the number of docks has the highest impact on the offload completion time as shown if Table 3. Given that 56% of all equipment items in the model are containers offloaded by cranes and a gantry crane is much faster then a ship's crane this result is not a surprise.

Throughput - All Equipment

Of the 7,200 runs, the proportion of runs where a particular equipment type was the last to arrive at its final destination has the following break down:

- ISO 87%
- HET 3%
- RS 1%
- MTVR 7%
- MTVR/RS 2%
- AMMO <1%

The MTVR/RS are cases where both the MTVR and RS were completed at the same time. This situation occurs because MTVRs are a subset of RS and both may travel in the same convoy. All pieces of equipment in the same convoy arrive at the destination at the same time.

The nine most significant factors that affect the final destination arrival time are listed in Table 4. Of these, the top eight factors are directly related to the throughput of containers. Considering that ISO containers finished last during 87% of the simulation runs this result is not surprising.

Factor	| Effect |
rtchdelay	407.9187
rtchcsa	401.8970
truckconvoy	212.9060
securityconvoy	202.0804
rtchpier	126.8719
aaoedistance	119.8650
gcranedelay	118.0914
dock	102.9512
sl3delay	100.9018

Table 4. Top nine factors including two-way interactions that effect the latest time for all equipment to arrive at its final destination(s).

The AMMO containers almost never finish last because they are formed into convoys directly on the pier and they have the highest priority when assigned convoy security.

Throughput - By Equipment Type

The overall time to complete the throughput does not paint a complete picture because it is highly influenced by the ISO containers. It is reasonable that equipment types with proportionally more equipment will take longer to throughput than those with proportionally lower equipment. In addition, individual equipment types use different sub-processes and resources during the throughput process.

Table 5 shows the top five factors that effect the throughput completion time of each equipment type. This table illustrates the ranking of factors across the equipment types.

First, it is clear that RTCH plays a significant role in the throughput of containers. Both the delay and the number of RTCHs are significant for ISO containers and the number of RTCHs at the pier is significant for the AMMO containers (Note 1).

The throughput of AMMO containers is affected more by the container offload rate (Note 2). This result occurs because the AMMO containers have the simplest throughput process as they are convoyed directly from the pier.

However, the AMMO containers are still affected by the number of security assets, as are all other equipment types (Note 3). Security plays a particularly strong role across the three vehicle equipment types.

The convoy transportation assets have high-ranking effects for each equipment type except AMMO containers (Note 4).

AMMO	ISO	RS	MTVR	HET
gcrane[2]	rtchdelay[1]	securityconvoy[3]	securityconvoy[3]	securityconvoy[3]
dock[2]	rtchcsa[1]	sl3delay[5]	gcrane[6]	hetconvoy[4]
securityconvoy[3]	truckconvoy[4]	rsconvoy[4]	sl3delay[5]	sl3delay[5]
rtchpier[1]	securityconvoy[3]	gcrane[6]	rsconvoy[4]	gcrane[6]
dock:gcrane[2]	rtchpier[1]	mechanics	dock:securityconvoy	mechanics

Table 5: Top five factors that impact the throughput completion time by equipment type. Notes for the factors are indicated by superscripts and explained below.

Note 1: The number of RTCHs and the RTCH Delays are highly ranked for the throughput of containers, particularly ISO containers. AMMO containers are less affected because they are convoyed directly from the pier.

Note 2: The dock and use of gantry cranes are highly ranked for the throughput of AMMO containers. AMMO containers have simplest throughput process as they are convoyed directly from the pier. Therefore, the offload rate has a larger effect on their throughput process than for that of other equipment types.

Note 3: The number of security assets is highly ranked across all equipment types and particularly for vehicles.

Note 4: The number of convoy assets is highly ranked for each equipment type except ammo containers.

Note 5: The SL3 setup delay is highly ranked for all of the vehicles.

Note 6: The use of gantry cranes is highly ranked for the vehicles, which do not explicitly use the gantry cranes. This situation may be because of the dependency created by the sharing of the security assets.

The SL3 setup delay is ranked highly across the vehicle equipment types (Note 5).

Surprisingly, MTVR armoring resources ranked 94th among the MTVR throughput completion time factors. This indicates that the armoring process is relatively unimportant to the final MTVR throughput completion time. However, the correlation between the proportion of runs where MTVR throughput completion is greater than or equal to RS throughput completion is -0.925 indicating that increasing the armoring throughput (more armoring resources) has an important effect on when the using units will receive their MTVRs relative to other RS vehicles.

MTVR Armoring Throughput	Completion of MTVR >= RS		Percent TRUE
	FALSE	TRUE	
1.397	3	447	99.3%
2.2195	51	849	94.3%
2.794	68	832	92.4%
3.6165	132	768	85.3%
4.191	139	761	84.6%
4.439	207	693	77.0%
5.0135	203	697	77.4%
5.836	195	705	78.3%
6.6585	101	349	77.6%

Table 6. The correlation between the proportion of runs where MTVRs throughput completion time is greater then the RS throughput completion time and the MTVR armoring throughput rate is -0.975.

Finally, the use of gantry cranes is ranked high for the RS and HET required vehicles (Note 6). This result implies that the offload rate of containers is somehow affecting the completion time of these two equipment types. The only cross dependency between the vehicles and the containers is via the convoy security assets.

Throughput - Flow Time

The factors that are significant to the mean equipment flow time (the time an item arrives at the final destination - the time it was offloaded) are listed in Table 7.

Container handling (RTCH Delay, number of RTCHs) has the largest effects. Considering that ISO containers comprise 42% off the equipment and every ISO container is touched three times by a RTCH during the throughput process it is not surprising that these factors have large effects.

Factor	| Effect |
rtchdelay	108.19988
rtchcsa	87.33917
securityconvoy	86.74715
sl3delay	56.81665
rtchpier	52.65566
mechanics:tpdrivers	49.61680
rtchdelay:rtchcsa	39.91947
mechanics:securityconvoy	37.93413
rtchpier:rtchcsa	37.71522

Table 7. Top nine factors including two-way interactions that effect equipment flow time

SUMMARY AND WAY AHEAD

This evaluation of the MPF Arrival and Assembly Model has identified key parameters and processes in the model that have high effects on the model's measures of effectiveness (throughput completion time, equipment flow time, and offload completion time). The most important factors and processes in the model are:

- The handling of containers including RTCH delays and the number of RTCHs in use.
- The number of convoy transportation and security assets.
- The use of gantry cranes or not.
- The SL3 setup delay.

These factors and processes should be the focus of future MPF exercise data collection efforts.

Additionally, future work on the model should focus on validating that the real world processes that are most significant to the model are adequately and accurately represented. For example, the convoying of equipment is currently grouped by both equipment type and destination. It may be more appropriate to have equipment of varying type but the same destination travel in the same convoy.